Papers

What we know about the Baltic Sea: a summary of BSSC 2005

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1. Introduction

The Baltic Sea, an internal sea of the European Community, is one of the largest brackish water bodies in the world. It is quite unique in many respects, particularly in its natural features and in the cultural, political and socio–economic patterns of the countries bordering it.

After nearly 40 years, during which Baltic marine physicists, chemists, biologists and geologists had been holding separate scientific meetings, it was decided the time was ripe to arrange joint scientific conferences with the purpose of getting together to discuss general and specific aspects of the Baltic Sea, to exchange information, to integrate efforts, and to get to know and understand each other better. The Sopot 2005 Congress, preceded by

the Baltic Sea Science Congresses in Rønne (1997), Warnemünde (1999), Stockholm (2001) and Helsinki (2003), was the fifth joint meeting of the Conference of Baltic Oceanographers (CBO), Baltic Marine Biologists (BMB) and Baltic Sea Geologists (BSG). Like all the previous congresses, the one held in Sopot bore witness to the idea that we all, members of CBO, BMB and BSG, should continue to work together even more closely.

The meeting in Sopot instigated discussion on a broad spectrum of problems, from large-scale climate change-related processes to local, small-scale specific Baltic Sea features. Further subjects for deliberation included modelling as a research tool and as a way of providing services and forecasting certain phenomena, operational oceanography, and man's impact on the Baltic Sea environment and its resources.

We are indebted to our Scientific Committee for their work during the past months to sort out and select interesting contributions to all the oral and poster sessions, and thus for making the Congress an attractive and quality event. We also thank the Polish Academy of Sciences and the City of Sopot for their financial support.

We hope that the joint Congress and fruitful scientific discussions it sparked will promote new contacts and pave the way to even closer cooperation between scientists involved in Baltic research.

Altogether, 274 abstracts were submitted for presentation. The International Scientific Committee selected 30 to be presented orally at the plenary sessions and 85 at thematic sessions; 151 contributions were presented as posters. There were 8 invited lectures, which dealt with broad questions such as climate change, the world's fisheries and ecosystem changes.

The Congress also organised five workshops on the following topics:

- Sea level change;
- The IODP project;
- Ventilation of deep waters in the Baltic Sea;
- New activities of the Helsinki Commission (HELCOM);
- The new EU-supported BONUS project.

2. The physical environment

2.1. Climate change

After 1991, the North Atlantic, the Arctic Ocean, and the land masses surrounding them experienced the 10 warmest years since 1951. At the same time, the North Atlantic Oscillation (NAO) winter index reached its maximum positive values in 175 years of records (Dickson, invited paper). Further evidence of warming provided by Bob Dickson includes the

reduction of sea-ice in the Arctic Ocean to the minimum in the winter of 2002–2003; a large increase in freshwater runoff to the Nordic Seas; and the 40-year-long freshening of the dense overflow over the Greenland-Scotland Ridge, which ventilates the Atlantic deep water. Freshening of the North Atlantic Ocean has been observed in the whole water column and can be tracked as far back as the Equator.

Obviously, this had to produce changes in the Atlantic Meridional Overturning Circulation (MOC) and influence the climate system of the neighbouring seas, including the Baltic. Indeed, records show an increase in the air temperature in the Baltic Sea catchment area (von Storch et al.) and changes in the climate of the Baltic Sea itself. Monthly mean sea surface temperatures (SSTs) have revealed that the seven warmest summers of the past century have occurred during the last 15 years and that SSTs have generally increased and more frequently exceeded 20°C (up to 25°C) (Siegel et al.). Winters have become generally milder, and spring warming starts earlier. Variations in the timing and pattern of spring and autumn have greatly affected the onset and intensity of phytoplankton blooms.

In the last 15 years, the yearly mean SSTs have been showing a positive trend of 0.8°K (Siegel et al.), the trend being dominated by summers and autumns. While a slightly negative trend has been evident in winter, the positive trend has been more distinct in the northern Baltic. The unusually warm water inflows observed during the last two-three summers (Mohrholz & Schuffenhauer, Feistel et al., Piechura) could be regarded as manifestations of climate change as well. Warm summer inflows sandwiched in the halocline of the Bornholm Deep have caused a strong temperature anomaly there. In October 2002, the halocline temperature was the highest ever recorded in the Bornholm Basin (Mohrholz & Schuffenhauer). Significant changes were observed around the year 1988, and the winter surface temperature and the intermediate water temperature in the Bornholm Basin have since increased by about 1°C. Since 1988, the warm seasons in the surface layer have lengthened. Mohrholz & Schuffenhauer provided evidence of a good correlation between the minimum intermediate winter water temperature and the NAO winter index.

Past climate changes can be inferred from bottom sediment deposits. From their analyses of the sediment record, Leipe et al. identified three separate climate cycles during the last 1000 years:

- 1850–2000 A.D.: a warm period with high salinity in the Baltic Sea, a strong halocline, anoxic conditions in the deep waters, high productivity and anthropogenic pollution;

- 1250–1850 A.D.: the little ice age, with lower salinity and a weak halocline, a mixed water column, well-oxygenated deep waters and lower productivity;
- 1000–1250 A.D.: the medieval warm period with high salinity and a strong halocline, anoxic deep waters and high productivity.

Detailed analysis of the two warm periods should allow, to some extent, the magnitude of anthropogenic effects to be assessed.

2.2. Water circulation

The last few years have seen considerable progress in research in Baltic Sea oceanography. The application of new measuring techniques and progress in modelling have made it possible to take a more in-depth look at dynamic processes, to describe and to simulate them. High-resolution CTD and ADCP measurements have revealed interesting details, enabling a completely new picture of the Baltic water column structure and movement to be drawn. One of the most important features being subjected to intensive investigation is the presence of mesoscale eddies. According to the data collected by the Institute of Oceanology, Polish Academy of Sciences (IO PAS), eddies of all scales, from less than 1 km to more than 100 km, are a nearly permanent feature accompanying water movement in the Baltic Sea, particularly in the deep/bottom water (Piechura). Observations confirm the conclusions, derived on theoretical grounds, that intrusions – like inflow water, which can also be regarded as gravity plumes entering a stratified medium – create rotational movements similar to eddies and meanders. It is assumed that eddies in the deep layer are crucial for the transformation of the Baltic Sea deep water.

Reissmann concluded that eddies occupy a constant proportion (12%) of the basin volume in every deep basin of the Baltic. He also stated that, theoretically, eddies are capable of disrupting stratification in about 20% of the halocline volume in the winter season.

Considerable attention was devoted to deep water dynamics (Piechura, Paka & Golenko, Feistel et al.). Deep water movement through the chain of deep basins and channels and over the shallow sills is very complex, with mesoscale eddies and internal waves being nearly permanent features. Breaking internal waves may contribute as much as c. 30% of the vertical mixing energy needed below the halocline (Nohr & Gustafsson). Intensive mixing of deep water takes place primarily in the following three major areas: the Arkona Basin, the Bornholm Deep and the Słupsk Furrow.

The near-bottom flows were found to move at a much higher rate than that estimated earlier, particularly when inflow waters were travelling along

the Baltic Sea bottom: currents up to 50 cm s^{-1} were measured (Sellschopp et al.).

After flowing over the Słupsk Sill, the deep waters move eastwards in portions, in a splash-like manner.

Phenomena such as intrusions, diffusion and diapycnal mixing were at the focus of a number of presentations (Kuzmina et al., Arneborg et al., Nohr & Gustafsson). Diffusivity from the dissipation of barotropic motion could explain the temporal evolution of salinity during stagnation periods (Nohr & Gustafsson). The role played by shallow banks in the water circulation turned out to be important (Axe & Lindow); this finding is particularly relevant, considering that numerous wind-turbine installations are planned in the shallow-bank areas of the Baltic.

2.3. Saltwater inflows and deep water ventilation

After 10 years without any major inflow event, one big inflow and some small ones were observed during 2002–2004. They were the best-ever investigated inflows, both in the Danish Straits and in the inner Baltic Sea. In former times, knowledge of major inflows into the Baltic was derived *post factum*, mostly from the changes they caused. Small and medium-sized inflows were hardly noticed at all. This time, even small such events could be recorded in the Straits and within the Baltic Sea and investigated. Some results of that research were presented at the plenary and CBO sessions, though primarily at the special workshop.

The most important findings relating to saltwater inflows and deep water ventilation can be summarized as follows.

- After a long period of stagnation (since 1993), the period 2002–2004 witnessed very unusual inflow activities: a warm summer inflow in 2002; a very cold inflow in January 2003; a warm summer inflow in 2003; a small cold, gale-forced inflow in January 2004; and, probably, another warm summer inflow in 2004 (Feistel et al., Piechura, Sellschopp et al., and others).
- The small cold inflow in January 2004 and the movement of the inflowing water in the western Baltic Sea were described by Sellschopp et al. The bottom current was observed to move at 0.5 m s^{-1} and to bifurcate.
- Medium-size and large inflows reach farther to the east, having travelled through the chain of deep basins and channels and flowing over the sills. Depending on the magnitude of inflow, the 'pure inflow' water can reach different basins – the stronger inflows bring relatively pure waters farther to the east. Entrainment and intensive mixing

take place in deep areas (Piechura). Over the Słupsk Sill, there is a different flow regime (Paka & Golenko).

- New instruments (e.g. the free-fall microstructure turbulence profiler) allowed the dissipation rate of turbulent kinetic energy and vertical eddy diffusivity to be measured and calculated (Fiekas et al.).
- Investigation and modelling of inflowing waters considered as gravity plumes revealed secondary circulation cells caused by Ekman wearing and entrainment processes (Burchard et al., Arneborg et al.).
- Subsurface cyclonic eddies and their contribution to deep water ventilation were observed and modelled (Zhurbas et al.), as was the role of internal waves, diffusivity, and energy dissipation (Nohr & Gustafsson).
- Numerous intrusions accompanying inflow/deep water movement were investigated and their contribution to diapycnal mixing and deep water ventilation described (Kuzmina et al.). Mohrholz reached a somewhat surprising, but very interesting, conclusion, whereby small inflow events contribute to the ventilation of subhalocline layers – inflow water gains oxygen in the Arkona Basin through mixing with the ambient water, and transports it farther to the east.
- Great progress in modelling inflows was demonstrated (Meier et al.)

2.4. Chemical oceanography

Generally speaking, the problem of nutrients was covered extensively during the Congress. The most interesting results involved the quantification of nutrient fluxes across the sediment-water interface and fluxes across the sea water-atmosphere interface (Lukkari & Leivuori).

Measurements carried out in the Gotland Deep have revealed a decreasing trend in dissolved cadmium concentrations there over the last ten years. The trend was discussed in the context of redox conditions, water inflows from the North Sea, and the dynamics of riverine runoffs. Decreasing concentrations and inventories were also concluded from heavy metals research in bottom sediments, and in the zooplankton. It may therefore be safely assumed that concentrations of most heavy metals in the Baltic have decreased over the last decade or so. This conclusion, however, may not be valid for mercury, since both surficial bottom sediments and atmospheric concentrations of the metal vary widely, so that the detection of long-term trends is not possible (Pohl & Hennings, Pempkowiak et al., Rozanow, Kravtsov et al.). Heavy metal concentrations in biota were extensively discussed as well.

The accumulation of persistent organic pollutants (POPs) by biota was shown to be related to both the concentration and the physicochemical properties of individual compounds. A promising method for averaging dissolved concentrations over a prolonged time period was presented. A relationship between the biological effects and the presence of organotin compounds in mussels and sediments was discussed and earmarked as an important field for the practical implementation of the research results (Schulz-Bull, Pazdro et al., Tsyban & Mosharova).

The results of research on the distribution of dissolved organic carbon (DOC) and nitrogen (DON) were presented, along with the factors influencing the concentrations of both species in the Baltic (Nagel, Schneider). These studies enabled the quantification of distributions and factors influencing carbon concentrations. The fate of particulate organic carbon and nitrogen was discussed as well. Several other presentations dealt with organic/inorganic nutrient loads, sources and trends. All this is indicative of a major effort directed towards the quantification of biogeochemical cycles in the Baltic and can be linked with large-scale projects aimed at assessing the contribution of coastal seas to carbon and nutrient budgets. The installation of an automatic water pCO_2 sensor on a ferry crossing the Baltic is a recent and important achievement in this respect.

With respect to more general subjects, it is obvious that measurements of total concentrations are often inadequate for understanding the mechanisms and rules governing the fluxes of chemical substances and the spatial and temporal changes in their concentrations. A number of studies reported widely employed chemical speciation in such instances. The classical chemical measurements are also increasingly being supplemented by simple mathematical models, allowing a better explanation of spatial and temporal variabilities in the chemical substances studied.

3. Marine biology

3.1. Changing ecosystem of the Baltic Sea

The topic of ecosystem variability, manifested as changes in physical, chemical and biotic factors on different time scales and giving rise to asynchronous fluctuations was introduced (H. Schubert). Different responses of various ecosystem components to different triggers (e.g. temperature, trophic interactions) were demonstrated. The presenter concluded that sieving through the irregular fluctuations to look for trends, particularly by analysing species with rapid reproductive cycles using multivariate methods, is difficult without evidence of direct causality. When analysing indirect

effects, the range of applicability of various ecosystem (biotic) indicators has to be defined or assumed.

Symptoms of changes in the Baltic Sea ecosystem also include the annual summer cyanobacteria blooms in the open waters. The growth of *Nodularia spumigena*, a diazotrophic cyanobacteria species causing toxic blooms, depends on actual iron bioavailability in the Landsort Deep, where *N. spumigena* blooms are commonplace in summer (Żeglińska et al.). Starting from the hypothesis that the transfer of low-molecular, directly bioavailable, iron forms from particulate and colloidal phases was relatively slow and that slow transfer may induce iron stress in certain algal species, it was concluded that iron concentrations and forms in the Landsort Deep were adequate to sustain the growth of *N. spumigena* in summer, that iron bioavailability may be temperature-limited, and that phosphorus limitation is important in other seasons.

Evidence of the increasing intensity of cyanobateria blooms in the Gulf of Finland was also forthcoming (Janssen et al.).

3.2. New perspectives in biology

Novel approaches for solving the problems encountered when studying biological and ecological phenomena in the Baltic Sea were presented. The study by Johannesson & André eshowed Baltic populations to be, on average, genetically c. 20% less diverse than conspecific Atlantic populations. It was also demonstrated that the Baltic is a refuge for genetically separate lineages of certain species, and that it houses genetically precious, but endangered populations of a number of species.

Research on the genetic differences between populations of the European *Mytilus* species (*M. galloprovicialis*, *M. edulis*, and *M. trossulus*) and within-basin genetic diversity showed clear differences between three groups of sites: the southern (from the Black Sea to the Atlantic coast), the northern (the Baltic and Barents Seas), and the central sites (Filipowicz et al., presented by Burzyński). With the application of genetic and molecular techniques, it was demonstrated that haplotype diversity in the Baltic *Mytilus* was only a little lower than that in European populations.

Advanced molecular and cytological techniques were also applied to describe striking morphological, histological and cytogenetic features of the Baltic clam (*Macoma balthica*) population in the Gulf of Gdańsk (Sokołowski et al.). The population is distinct in that it exhibits a very high prevalence of shell deformation, as well as a high incidence of neoplasia and tumours. These effects were found to be adaptive responses at the morphological and cellular levels to adverse environmental conditions, primarily hypoxia/anoxia (reduced oxygen content in the water overlying

the sediment and the presence of hydrogen sulphide in the sediment) and sediment toxicity.

Methods of palaeoenvironmental analysis (ecological tolerances, proportions of ecological groups, transfer functions and modern analogue techniques, intraspecific morphological variations) were used to explore subfossil assemblages of ostracod shells found in sediment samples collected in the south–western part of the Baltic Sea (Frenzel). Those methods were used to directly reconstruct the salinity, substrate type, oxygen concentration, water depth and energy, erosion/deposition regime, productivity and temperature in the area. The direct reconstructions serve, in turn, as a basis for the indirect reconstruction of climate shifts, sea level variations, eutrophication intensity and sedimentation processes. Frenzel illustrated various approaches to palaeoreconstructions with examples drawn from his research on the ostracod thanatocoenoses he studied in the south–western Baltic.

3.3. Bioinvasions

Invasions of non-indigenous species (NIS) are an important problem for the Baltic Sea, and many presentations dealt with them, with respect to both different regions (eastern part of the Gulf of Finland, coastal lagoons, open waters) and different species. It was stressed that existing knowledge is sufficient for predicting possible impacts on the ecosystem of the Gulf of Finland (Orlova at al.). The increasing risk of future invasions over time, resulting from intensified shipping, climatic effects and increasing ecosystem susceptibility to invasion, was emphasised, as was the need for integrated NIS monitoring and agreement on monitoring protocols. The development of tools for mitigating the consequences of NIS invasions was stressed.

The characteristics that make a system susceptible to invasion (vacant niches, habitat disturbance, ecosystem properties altered by previous invasions, increased amounts of unused resources) were highlighted (Olenin). Contrary to expectations, there is no evidence of habitats with low species richness being more susceptible to invasion. Coastal lagoons are more prone to invasion than open sea habitats, and those habitats modified, naturally or anthropogenically or by previous invasions, are the most vulnerable. The modified HELCOM biological monitoring system should therefore focus on coastal lagoons, inlets and ports.

There is evidence of a rapid expansion of NIS in the Baltic Sea since the 1990s and a substantial impact on the Baltic plankton is expected (Karjala & Lahdes). The study revealed the high carbon and nitrogen contents of an alien cladoceran and its high potential for consumption as a prey item, hence the importance of the species in the food web. The

question whether the hepatotoxins produced by *N. spumigena* were able to restrict the extent of an alien fish species' invasion received a negative answer (Sapota): cyanotoxins were found to be ineffective in controlling the invasion of the round goby, owing to the fish's high resistance. Harmful algal blooms and bioinvasions were therefore two independent factors producing environmental disturbance in the Baltic.

Numerous data on alien species, such as the round goby, Chinese mitten crab and an oligochaete were presented as well. The round goby was found to be firmly integrated with its new ecosystem and to constitute a potentially important food source for predators in the system and for humans (Sapota). On the other hand, the species competes for food with the flounder, affects its recruitment, and – coupled with fishing pressure – poses a real threat to native fish species (Almqvist et al.). The wide distribution and increasing abundance of the Chinese mitten crab and its function in the ecosystem (potential competitor, food source, habitat provider, transportation vector for other organisms) was pointed out.

Many aspects of other problems were discussed, e.g. ecosystem structure, pelagic and benthic processes, eutrophication, and methods of field and laboratory research.

4. Baltic Sea geology

Since their presence just as observers at the first and second BSSC in 1997 and 1999, the marine geologists have steadily been intensifying their activities. During the 2001 Congress in Stockholm, a broad range of geological problems was discussed; indeed, the geological contribution constituted – both quantitatively and qualitatively – a substantial part of that Congress. At that time, too, the Baltic Sea Geologists (BSG) was established as an organisation, its main responsibility being to participate in the arrangement of subsequent Baltic Sea Science Congresses and to take care of the marine geology part of the Congress programmes. As a result, both the Helsinki (2003) and Sopot (2005) Congresses were co-organised by the BSG.

The main topics in Baltic geology discussed at the Sopot BSSC included:

- The last Glacial cycle and records of climate changes;
- Sediments and environmental change, processes and effects;
- Modelling of sedimentary processes and coastal geology;
- Human impact on bottom sediments end environmental geology;
- Evolution of the Baltic Sea area and sediments;
- Sea bed mapping and sediments.

The reconstruction of past climate changes on the basis of bottom sediment analyses was one of the main subjects presented and discussed. Knowledge of past climate oscillations is very important for understanding the present and forecasting future changes.

Another very popular and broadly discussed topic was that of coastal processes, such as coastal erosion, its causes, rate and range. A link to sea-level and climate changes was suggested. Both natural and anthropogenic (dam construction, harbour operation, ship waves) causes were investigated in this respect. Strong emphasis was placed on coastal management by the appropriate agencies; the interest may well have been triggered by the expected sea level rise.

Sea bottom mapping and shore development at various stages of the Baltic Sea's history, as well as the geochemistry of surface sediments with respect to heavy metals and organic substances (distribution and association with sediment properties) were further topics of discussion.

5. Modelling

Modelling was one of the most extensively covered topics at the BSSC 2005, with over 25 oral and many more poster presentations. However, most importantly, modelling has become a widely used research tool in a broad range of ocean science branches, including biology, ecosystem study and marine geology, in addition to marine physics and water dynamics.

Considerable progress has been achieved in the modelling of inflows, deep water mixing, and ventilation. These are very important questions, fundamental for the ecosystem's functioning. Attempts to model some other phenomena associated with mixing processes, such as gravity plumes (inflow waters travelling within the Baltic deep areas), eddies and intrusions, diffusion, turbulence and upwelling, were also presented. Models of general and regional water circulation showed further improvement. Some results of modelling sea level, sea ice cover, and waves were presented as well. Operational oceanographic modelling was mentioned, but this is going to need more attention in the near future. Very interesting trials of coupled physical-biological modelling were presented, including ecosystem models, eutrophication, algal blooms and CO_2 cycles.

Also worth mentioning is the numerical modelling of sand sediment transport and other geological processes presented by the marine geologists.

6. Information, human impact, management

Information on ongoing research projects, e.g. BALTEX, and network-focused projects such as BONUS was disseminated to the Congress audience.

The Baltic Sea Experiment (BALTEX) – a GEWEX project – has been coordinating research on energy and water exchange in the Baltic Sea catchment area since 1994. The BALTEX Phase II (2003–2012) is currently being implemented. The latest initiative – the BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC) – will assemble, integrate and assess available knowledge of historical, current and expected future climate change and its impacts in the Baltic Sea basin. The overall objective of BACC is to publish an assessment book by 2006.

BONUS – the network of Baltic Sea science funding agencies – is an EU project aimed at promoting cooperation between these agencies for the development of marine sciences in the states around the Baltic.

Examples of negative human effects (are there any positive ones?) in the Baltic Sea environment include eutrophication, overfishing, bioinvasions and coastal erosion. During the Congress, eutrophication received less attention than in previous years. Could this be a sign that conditions in the Baltic Sea are improving?

The Baltic fisheries are a highly controversial issue, as the area has witnessed many conflicts and an intensive management effort. The Baltic fishery problems were placed in a broader context of global fisheries trends by Pauly (an invited speaker talking on 'Exclusive Economic Zones and the structure of global fisheries'), who described the steady erosion of fisheries worldwide and the decline in global fisheries that has intensified since the late 1980s, after the Exclusive Economic Zones (EEZ) were established. He said that EEZs had been conceived as a means of preventing the decline and overfishing, but in fact the opposite had happened as a result of access agreements. Pauly discussed the present global trends that involve expansion of fisheries towards greater depths and, as a result of the decimation of large fish (top predators), 'fishing down', i.e. targeting the fish at lower trophic levels. He said that 'fishing down' was in fact one of the reasons behind the use of mean trophic levels as an index of biodiversity (the Marine Trophic Index) by the Convention on Biological Diversity. Pauly showed that the Baltic Sea is one of the areas experiencing the largest reduction in the Marine Trophic Index. Turning again to the broad picture, he concluded his talk by stating that a situation may be imagined where fishing in deep waters may become too expensive, thus protecting humans from their own folly.

Human impacts evidenced by bioinvasions and coastal erosion have already been highlighted in the previous sections. It needs to be reiterated, however, that the coastal erosion of the southern shores in combination with the sea-level rise caused by the glacioisostatic movement and climate change can become a really serious problem. Estonian scientists presented

some local problems of coastal and bottom erosion caused by frequent fast ferry traffic.

A set of new problems may emerge as plans to construct sea-based wind farms are pursued. The hundreds of such installations planned in the Arkona Basin could considerably intensify mixing of deep/inflow waters in the area. This would reduce the density of the water, causing it to move into the Bornholm Deep and father to the east via the intermediate layer instead of through the near-bottom one, thus preventing its ventilation. The problem is the main focus of the QUANTAS project.

The installation of a gas pipeline on the bottom could cause ecological problems, primarily but not only for the benthic communities.

The Congress participants were given information on developments in operational oceanography and on the Baltic Oceanographic Operational System (BOOS), as well as on the meta-data EDIOS project, and the computer-based NEST system, offering a decision support system for nutrient reduction in the Baltic Sea.

7. Summary

Based mainly on research done during the last 2–3 years, the body of knowledge presented at the 5th Baltic Sea Sciences Congress is impressive. It demonstrates that great progress has been made towards understanding physical, chemical, biological and geological processes, and in modelling. Observed climate changes in the North Atlantic – Arctic Ocean area have been reflected in the Baltic Sea climate variations during recent decades. The increase in SST, variations in the timing of spring (earlier) and autumn (later), and the frequency of warm inflows in summer are evidence of these changes. Bottom sediment core analyses exhibit long-term climate changes. We are now in a warm period like that of 1000–1250 A.D., with the one substantial difference – the strong anthropogenic pressure of today.

The application of new measurement techniques and progress in modelling, the better understanding of physics and the growing computing capabilities, have made it possible to look deeper into processes, to describe and to simulate them.

The role of mesoscale eddies and diffusivity in the properties transport and mixing was strongly underlined, as was the role of internal waves.

After 10 years without any major inflow event, one large inflow and some small ones were observed during 2002–2004. They are the best-ever investigated inflows, both in the Danish Straits and in the inner Baltic Sea.

Inflow water movement with the Baltic Sea, entrainment, mixing and transformation were described. Current speed of up to 50 m s^{-1} and intensive mixing in the Arkona Basin were recorded. Other areas of

intensive mixing are the Bornholm Deep and Słupsk Furrow. On the basis of measurements carried out in the Gotland Deep, we may assume that concentrations of most heavy metals in the Baltic Sea have decreased in the last ten years; mercury, however, bucks this trend. It was demonstrated that the accumulation of persistent organic pollutants (POPs) by biota is related to both the concentrations and the physicochemical properties of individual compounds.

Results of research on the distribution of dissolved organic carbon (DOC) and nitrogen (DON), and the factors influencing their concentration and fate were presented.

Symptoms of changes in the Baltic Sea ecosystem also include the annual summer cyanobacteria blooms in the open waters. The growth of *Nodularia spumigena*, a diazotrophic cyanobacteria species causing toxic blooms, depends on current iron bioavailability in the Landsort Deep, where *N. spumigena* blooms are commonplace in summer.

Novel approaches to solving the problems encountered when studying biological and ecological phenomena in the Baltic Sea were presented. The study by Johannesson & André showed Baltic populations to be, on average, genetically c. 20% less diverse than conspecific Atlantic populations. It was also demonstrated that the Baltic is a refuge for genetically separate lineages of certain species, and that it houses genetically precious, but susceptible populations of a number of species.

Advanced molecular and cytological techniques were applied to describe striking morphological, histological and cytogenetic features of the Baltic clam (*Macoma balthica*) population in the Gulf of Gdańsk.

Invasions of non-indigenous species (NIS) are an important problem for the Baltic Sea and many presentations dealt with them, with respect to both different regions (eastern part of the Gulf of Finland, coastal lagoons, open waters) and different species.

The characteristics that make a system susceptible to invasion (vacant niches, habitat disturbance, ecosystem properties altered by previous invasions, increased amounts of unused resources) were presented (Olenin). Contrary to expectations, there is no evidence that habitats with low species richness are more likely to be invaded. Coastal lagoons are more prone to invasion than open sea habitats, and those habitats modified, naturally or anthropogenically or by previous invasions, are the most vulnerable.

Reconstruction of past climate changes, derived from bottom sediment analyses, was one of the main subjects to be discussed.

Another very popular topic was that of coastal processes, such as the causes, rate and range of coastal erosion. A link to sea-level and climate changes was suggested. Both natural and anthropogenic (dam construction,

harbour operation, ship waves) causes were investigated in this respect. Strong emphasis was placed on coastal management by the appropriate agencies; this interest may well have been triggered by the expected sea level rise.

With over 25 oral and many more poster presentations, modelling was one of the most extensively covered topics. Most importantly, however, modelling has become a widely used research tool in a broad range of ocean science branches, including biology, ecosystem study, and marine geology, in addition to marine physics and water dynamics.

Examples of negative human effects (are there any positive ones?) in the Baltic Sea environment include eutrophication, overfishing, bioinvasions and coastal erosion. During the Congress, eutrophication received less attention than in previous years. Is this a sign that conditions in the Baltic Sea are improving?

The Baltic fisheries are a highly controversial issue, as the area has witnessed many conflicts and an intensive management effort. The Baltic's fishery problems were placed in a broader context of global fisheries trends.

New problems are likely to emerge as plans to construct sea-based wind farms and a gas pipeline on the sea-bed, among others, are pursued.

The list of presentations discussed in this paper:

Almqvist G., Karlson A., Appelberg M., Skóra K., *Resource partitioning between Flounder and the non-indigenous Round goby in the Gulf of Gdańsk, Baltic Sea*, [in:] *Abstracts*, 5th Baltic Sea Sci. Congr. 'The Baltic Sea changing ecosystems' (Sopot, Poland, 20–24 June 2005), CBO, BMB, BSG, Sopot, 147–148.

Arneborg L., Fiekas V., Burchard H., *Mixing and dynamics of a gravity plume – observations, theory, and modeling*, [in:] *Abstracts*, (op. cit.), p. 106.

Axe P., Lindow H., *Hydrographic conditions over Baltic banks*, [in:] *Abstracts*, (op. cit.), p. 61.

Burchard H., Lass H. U., Mohrholz V. et al., *Dynamics of medium-intensity dense water plumes in the Arkona Basin, western Baltic Sea*, [in:] *Abstracts*, (op. cit.), p. 105.

Dickson B., *Hydrographic changes in northern seas and their impact on the ocean circulation and climate*, [in:] *Abstracts*, (op. cit.), 1–2.

Feistel R., Nausch G., Hagen E., IOW, *Unusual inflow activity 2002/3 and varying deep-water properties*, [in:] *Abstracts*, (op. cit.), 114–115.

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